

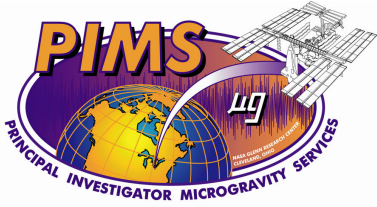
# Impacts of the Microgravity Environment on Experiments

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## Section 16: Impacts of the Microgravity Environment on Experiments

***Richard DeLombard***  
***Acceleration Measurement Discipline Scientist***  
***NASA Glenn Research Center***

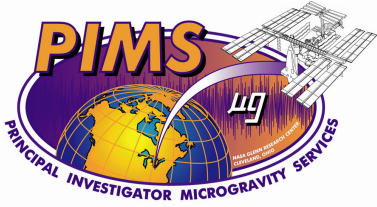


# Impacts of the Microgravity Environment on Experiments



## Introduction

- **Earth-bound experiments are affected by normal gravity and vibrational forces which exist in ground laboratories.**
  - gravity, elevators, air conditioner, traffic, people
- **Most microgravity experiments desire:**
  - zero-gravity,
  - constant, uni-directional acceleration, and/or
  - constant conditions.
- **Taking experiments to orbit removes effects of gravity but trades above disturbances for others**
  - gravity gradient, aerodynamic drag, thrusters, other experiments, crew members, Shuttle subsystems

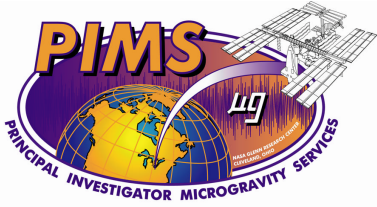


# Impacts of the Microgravity Environment on Experiments



## Improve the Environment

- **Microgravity environment is close to “zero-g” conditions, but still precautions need to be taken.**
  - **operational inhibits**
    - typical: attitude free-drift, crew exercise, & equipment operations
    - non-typical: Ku-band antenna & crew motion
  - **Orbiter attitude and altitude requirements**
    - Shuttle attitude determines the relative direction of the quasi-steady acceleration
    - slight attitude changes have effect on frequency of VRCS jet firing
    - amount of deadband in attitude control has effect on frequency of VRCS jet firing
    - Shuttle altitude has effect on the magnitude of the drag component and fluctuations thereof, especially if orbit is not circular

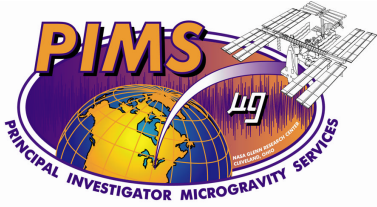


# Impacts of the Microgravity Environment on Experiments



## Microgravity Science Experiment Successes

- **Vast majority of microgravity science experiments have been successful**
  - **success has been due to a number of factors**
    - prior ground based research
    - PI involvement and extensive review process during experiment design and development
    - mission planning and operational simulations
    - crew interest and training
    - support for PI teams during mission
    - microgravity environment which can be supplied by the Shuttles, Mir, parabolic flight aircraft, sounding rockets, and free flyers
- **Some problems have occurred with experiments**
  - **difficulties with a few factors**
    - hardware failures on-orbit
    - modified mission parameters
    - unexpected operational scenarios
    - microgravity environment violated requirements

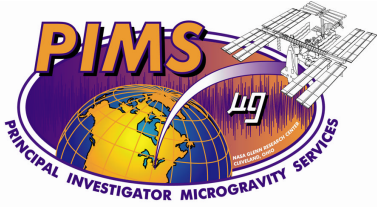


## Impacts of the Microgravity Environment on Experiments



### Advanced Automated Directional Solidification Furnace on USMP-2 / Lehoczky

- **High temperature furnace**
  - five zones, Bridgman-Stockbarger-type furnace
  - reduced stratification and fluid flow desired in microgravity
  - three Orbiter attitudes created different quasi-steady acceleration levels at furnace location
- **Two attitudes presented unstable conditions**
  - acceleration aligned with sample cold-to-hot
  - convective situation liable to lead to fluid flow
- **Perpendicular / transverse acceleration ratio**
  - less than one for all three attitudes
  - also conducive for fluid flow

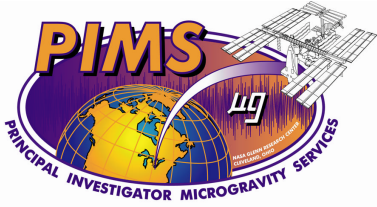


## Impacts of the Microgravity Environment on Experiments



### AADSF on USMP-3 / Fripp

- **Objective of experiment:**
  - The primary objective of this flight experiment was to examine the effect of the direction of the microgravity vector on the convective mixing of the liquid during directional solidification.
- **Method:**
  - three sample cells
  - three Shuttle attitudes (one for each cell)
    - thermally stable but solutally unstable in a one dimensional analysis
    - solutally stable but thermally unstable in a one dimensional analysis
    - horizontal growth
- **Unplanned attitude change**
  - cell #1 processing interrupted for free drift
  - acceleration vector alignment angle went from 2° to 45°
  - result appears to be solidification in accordance with a fully mixed condition as opposed to the desired diffusion condition



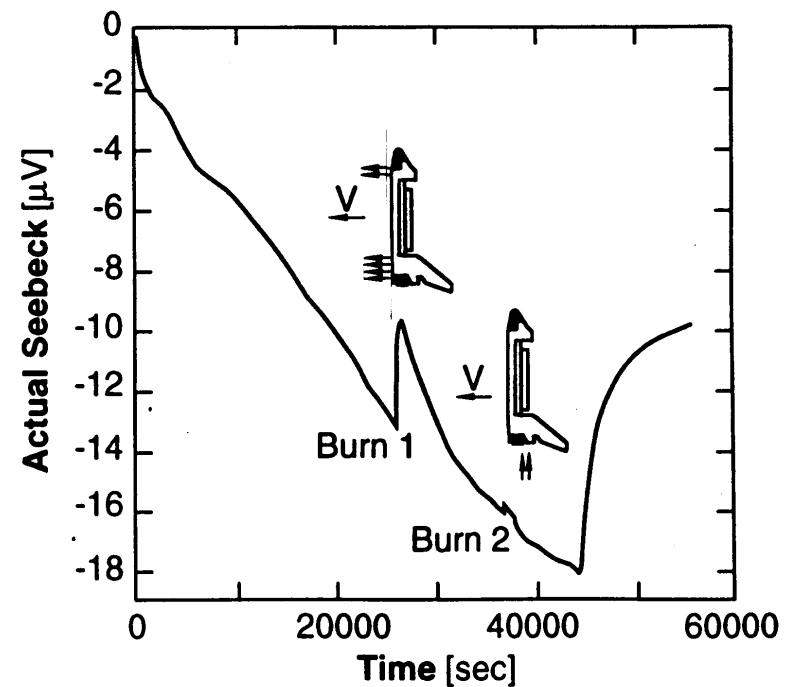
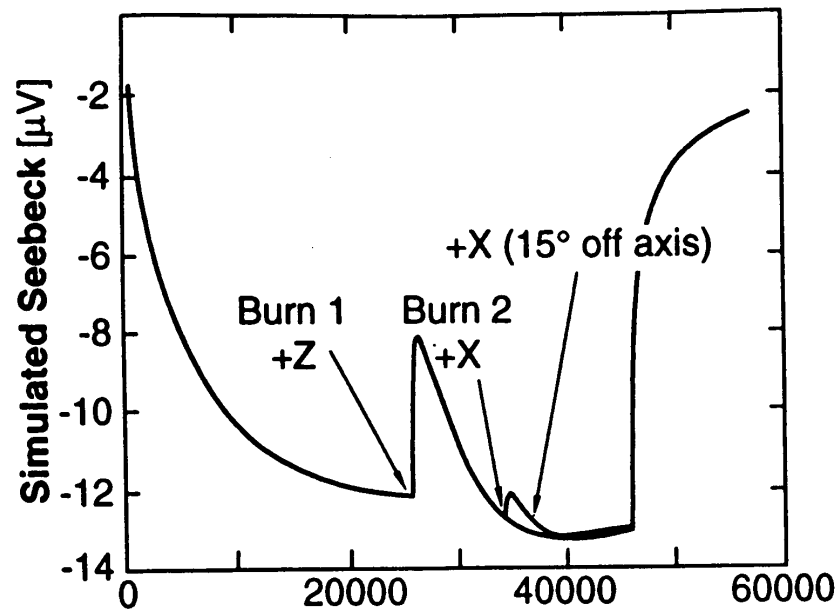
## Impacts of the Microgravity Environment on Experiments



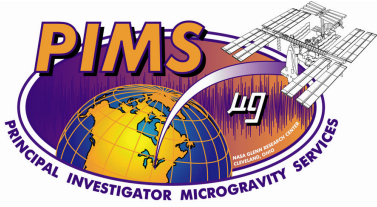
### MEPHISTO on USMP-3 / Favier

- **High temperature furnace**
  - metal alloy samples
  - in-situ measurement of Seebeck voltage indicating average melt composition at interface
- **One objective was to quantitatively characterize microgravity effects on an actual crystal growth experiment**
- **Thruster firing effects**
  - high acceleration levels cause convective mixing
  - interfacial composition disturbed
- **Summary results**
  - PRCS thruster: approximately one hour to recover from short thruster firing of 10 to 25 seconds durations
  - OMS thruster: approximately sixteen minutes to recover from short (35 seconds) duration OMS firing

## Response to PRCS & OMS Thruster Burns





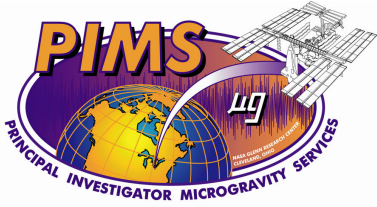


## Impacts of the Microgravity Environment on Experiments



### Indium Float-zone Furnace on STS-32 / Dunbar & Thomas

- **Fluid Experiment Apparatus**
  - float-zone materials processing furnace in middeck
  - Indium sample
  - Eigen-frequencies in 0.1 to 10 Hz range
  - crew treadmill exercise and thruster firing disturbances
- **Acceleration measurements made with Honeywell In-Space Accelerometer (HISA)**
  - mounted on front of Fluid Experiment Apparatus

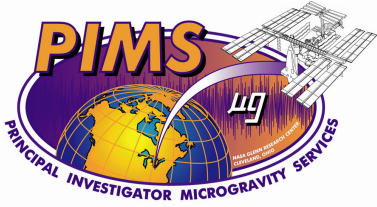


## Impacts of the Microgravity Environment on Experiments



### Movement of Particles on IML-1 / Trolinger

- **Movement of particles with different densities**
  - secondary science experiment within the Fluids Experiment System facility to grow triglycine sulfate crystals
  - tracer particles of three sizes (small, medium, large)
  - tracer particle motion was studied relative to fluid convection and the microgravity environment
  - correlations established between particle motion and acceleration environment
  - the growth solution is still far from the static system originally envisioned by microgravity scientists

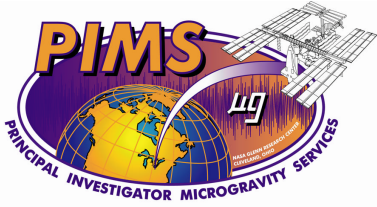


## Impacts of the Microgravity Environment on Experiments



### **GaAs crystals during USML-1 / Matthiesen**

- **Experiment conducted in the Crystal Growth Furnace**
  - examined the radial dopant distribution with the quasi-steady microgravity vector
  - microgravity vector acted perpendicular to the growth direction (i.e. transverse acceleration)
- **Results**
  - microgravity environment was quantitatively linked to the quality of the crystal
  - complete-mixing profile of the crystal was caused by the crucible-melt interface shape and not by the microgravity environment



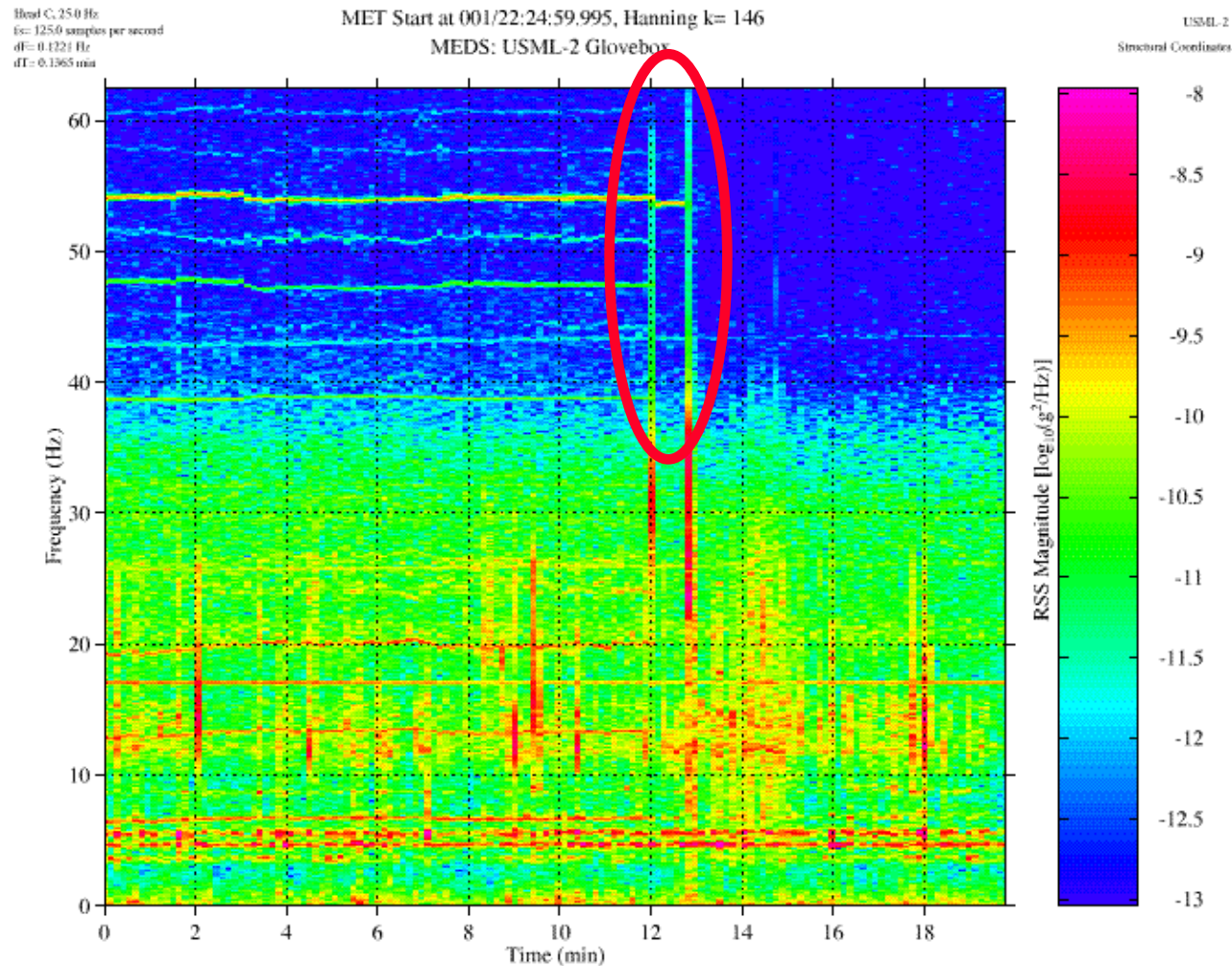
## Impacts of the Microgravity Environment on Experiments



### Surface Tension Driven Convection Experiment on USML-2 / Ostrach

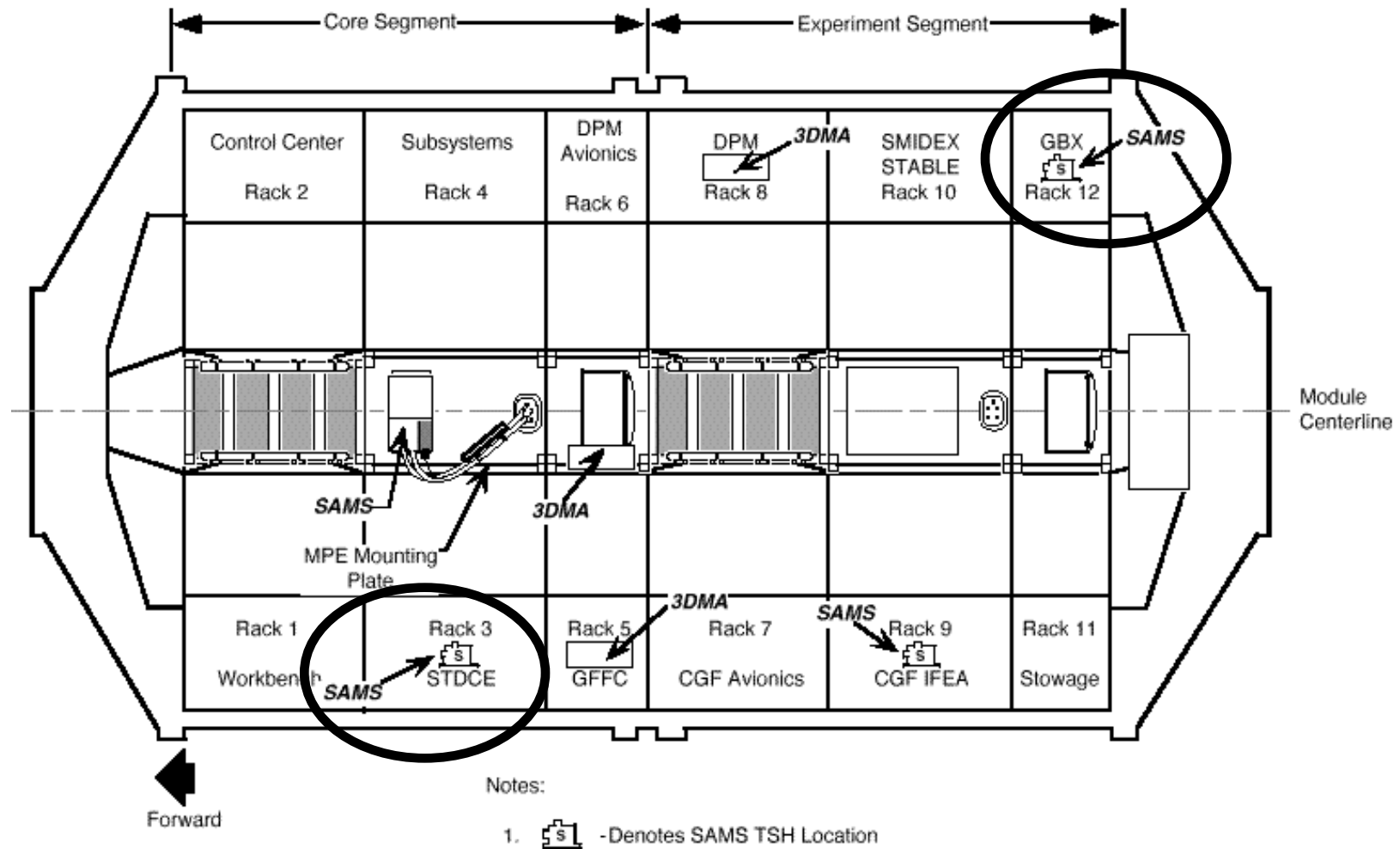
- **STDCE sample container**
  - free liquid surface of silicone oil
  - study of surface tension driven convection with different fill levels
- **Disturbances noted during operations**
  - ripples on free liquid surface
  - correlation established between glovebox fan operation, experiment video downlink, and downlink acceleration data
  - disturbance transmitted along and across aisle of Spacelab module

## USML-2 Glovebox Fan De-activation

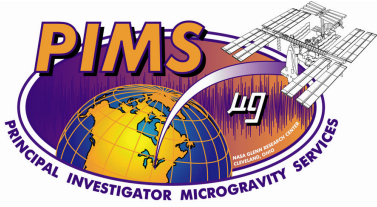


# Impacts of the Microgravity Environment on Experiments

## Location of STDCE and Glovebox on USML-2





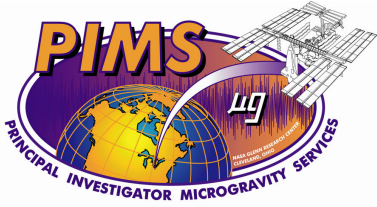


## Impacts of the Microgravity Environment on Experiments



### Confined Helium Experiment on USMP-4 / Lipa

- **Liquid helium sample**
  - temperature about 2 K
  - low mass
- **Pre-mission concern about structural resonances**
  - narrow frequency bands around 55, 75, & 119 Hz
  - 3rd harmonic of Ku-band antenna dither (~51 Hz) was a particular concern
  - Unexpected disturbance was observed around 56 Hz during initial part of mission
  - evaluated SAMS data in real-time and off-line to determine source



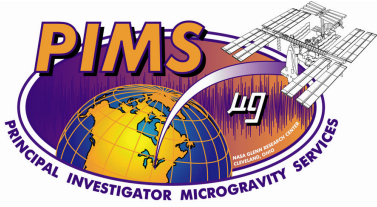
## Impacts of the Microgravity Environment on Experiments



### USMP-4 Inter-Experiment Disturbance

- Early in the mission, an unexpected signature appeared around 56 Hz
- PIMS notified the CHeX team of the observation, as well as the other USMP-4 science team via flight notes
- Near real-time plots were provided to the CHeX team in an effort to characterize this disturbance source
  - Based on the stability observed in these plots, the CHeX team was able to adequately compensate the CHeX data for this disturbance
  - Analysis of the activation times for the other USMP-4 payloads indicated the IDGE experiment introduced the 56 Hz disturbance to the environment upon their activation



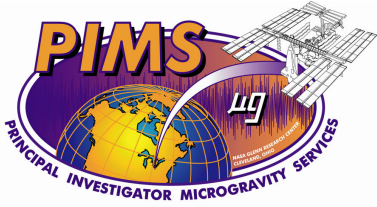


## Impacts of the Microgravity Environment on Experiments



### USMP-4 Disturbance Source Identification

- **Source of the 56 Hz disturbance was determined to be IDGE cooling fans**
- **Additional disturbance sources at 37 Hz and 74 Hz were introduced by the IDGE experiment hardware**
- **Although IDGE had flown on previous USMP missions, the disturbances were unknown because of lower cutoff frequencies for SAMS sensors flown on those previous USMP missions**
- **Post-mission ground test with IDGE flight experiment hardware and SAMS flight hardware confirmed the flight data conclusions**

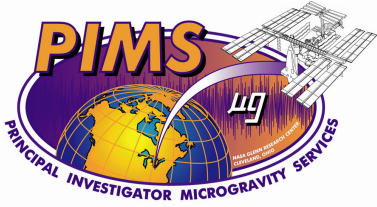


## Impacts of the Microgravity Environment on Experiments



### USMP-4 Operations Dodged a Bullet

- One of the IDGE cooling fans operated in the 37 Hz region
  - The operating speed of this fan was variable
  - Thus the vibration disturbance was a varying frequency
- LPE compensation
  - A variable frequency disturbance near a structural mode of LPE would have been very difficult or impossible to compensate
  - Likely would have resulted in curtailed operation of LPE, IDGE, or both during USMP-4

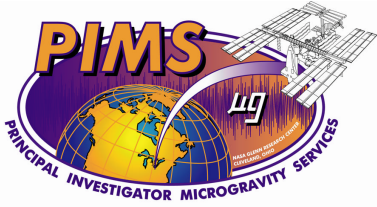


## Impacts of the Microgravity Environment on Experiments



### Protein Crystal Growth / various PIs

- **Nominal operations require quiet vibratory acceleration environment ( $<10^{-4}$  g) for first 24 - 48 hours for crystal nucleation**
- **On missions with significant disturbances, showers of small crystals have been observed**
- **Correlations between growth rate and crew exercise periods have been observed**



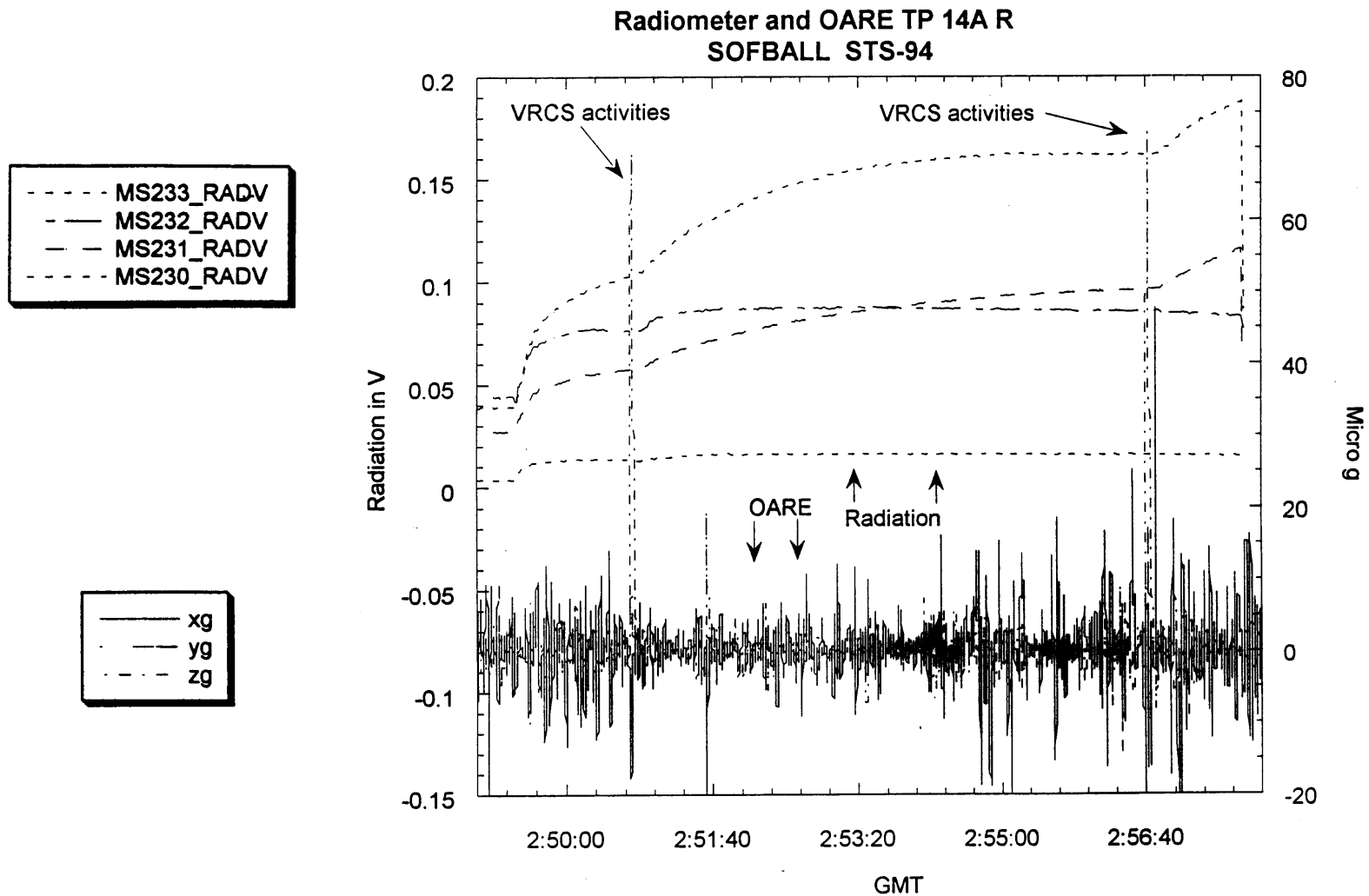
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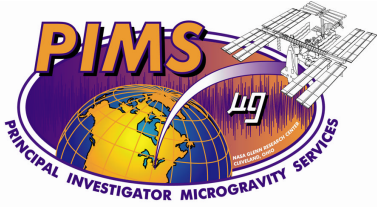


### Structure of Flameballs at Low Lewis Numbers on STS-94 / Ronney

- Thruster (VRCS jets) disturbances caused significant, long-lasting perturbations to the radiation readings
  - effect appears to last several minutes
- PI did not request free-drift periods pre-mission
  - need became apparent during early experiment operations
  - another PI team had a pre-mission "no-free drift" requirement
  - SOFBALL monitored the location of the Orbiter within the attitude deadband and initiated operations accordingly
  - Achieved maximum 5-minutes in deadband drift at beginning of their 14 minute test sequence
- PI is investigating the cause
  - flame ball surrounded by much larger region (a few cm in diameter) of hot gas - very sensitive to any acceleration
  - radiometers respond sharply when acceleration deforms the hot gas and shifts closer to or further away from the radiometer

# Impacts of the Microgravity Environment on Experiments



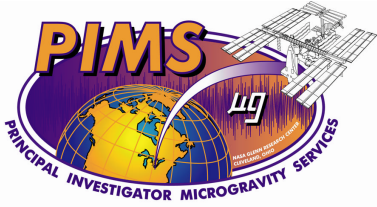


## Impacts of the Microgravity Environment on Experiments



### Structure of Flameballs at Low Lewis Numbers (SOFBALL) / Ronney

- Planned re-flight of SOFBALL on STS-107
- PI included requirements for low-frequency acceleration measurements
- PI has re-affirmed these requirements during PAYLOAD manifesting negotiations
  - Initial difficulty in manifesting OARE accelerometer
  - PI's requirements ensured that OARE would be manifested

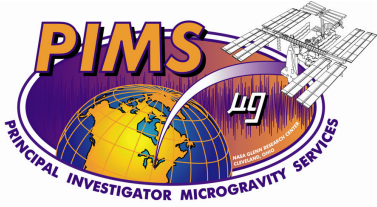


## Impacts of the Microgravity Environment on Experiments



### Isothermal Dendritic Growth Experiment on USMP-2 & -3 / Glicksman

- For all practical purposes, with respect to dendritic growth for the chamber size and temperature range selected, the microgravity environment aboard the Shuttle is at “zero-g,” i.e., convective effects are not seen on-orbit.
  - convection exists at 1 g
  - convection not apparent at 1  $\mu\text{g}$
  - convection not apparent at 40  $\mu\text{g}$  during Tether Satellite System deployment on STS-75
  - no disturbance for 40  $\rightarrow$  0.5  $\mu\text{g}$  transition when TSS broke
  - threshold somewhere between 1  $\mu\text{g}$  and 1 g but apparently above the Shuttle environment



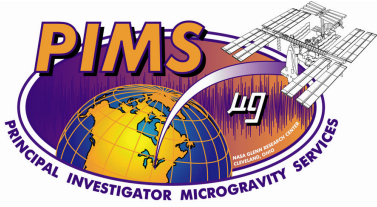
# Impacts of the Microgravity Environment on Experiments



## Summary

- The microgravity environment is not “zero-g” or even “zero-acceleration”. It is dynamic.
- The microgravity environment may influence the results of a science experiment.
- Analyses and/or tests should be performed before flight to investigate the sensitivity of an experiment to the microgravity environment.
- Environments of past missions should be considered in planning future experiments.
- Experiment teams should be concerned about what disturbances they may be causing to the microgravity environment with (for example) moving parts or required crew actions.



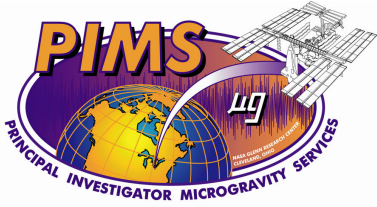


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## References

- Dunbar, B. J. , R. L. Giesecke, and D. A. Thomas: “The Microgravity Environment of the Space Shuttle Columbia Payload Bay During STS-32.” NASA TP-3141, 1991.
- Schoess, J. N. , B. J. Dunbar, D. A. Thomas: “Microgravity Environment Measurements On Board Space Shuttle Columbia on STS-32.” SENSORS, Vol. 7, No. 11, October 1990, pp. 15-19.
- Rogers, M. J. B., J. I. D. Alexander, and Schoess, J. : “Detailed Analysis of Honeywell In-space Accelerometer Data - STS-32.” Microgravity Science and Technology, vol. VI, issue 1, pp. 28 - 33, 1993
- Ramachandran, N., Frazier, D. O., Lehoczky, S. L., and Baugher, C. R.: “Joint Launch + One Year Science Review of USML-1 and USMP-1 with the Microgravity Measurement Group.” NASA CP-3272, 1994
- Curreri, P. A. and McCauley, D. E.: “Second United States Microgravity Payload: One Year Report.” NASA TM-4737, 1996
- Fripp, A. L., Debnam, W. J., Rosch, W. R., and Narayanan, R.: “The Effect of Microgravity Direction on the Growth of PbSnTe.” Launch + One Year Report (USMP-3), 1997



# Impacts of the Microgravity Environment on Experiments



## References (cont'd)

- Alexander, J. I. D., Garandet, J. P., Favier, J. J., and Lizee, A.: “Quantitative Experimental Characterization of g-jitter Effects on Directional Solidification.” AIAA97-0675, 1997
- Rogers, M. J. B. and DeLombard, R. : “Summary Report of Mission Acceleration Measurements for STS-73.” NASA TM-107269, 1996
- Snell, E. H.; Boggon, T. J.; Helliwell, J. R.; Moskowitz, M. E.; and Nadarajah, A.: “CCD video observation of microgravity crystallization of lysozyme and correlation with accelerometer data.” Submitted to Acta Cryst. D., 1996.